I. GENERAL INFORMATION

1. Legal name of applicant: City of Fort Worth

2. Participating political subdivisions: City of Fort Worth

3. Official representative:

   Greg Simmons, Assistant Director,
   Storm Water Management Division,
   Transportation and Public Works Department,
   1000 Throckmorton Street,
   Fort Worth, TX 76102
   Phone: 817-392-7852; Fax: 817-392-2433;
   Email: Gregory.Simmons@fortworthtexas.gov

4. Total project cost: $632,309.00

5. Total grant funds requested from the TWDB: $247,378.00

6. Applicant cash contribution to the study: $ 350,000.00

7. Source of cash contribution: Stormwater Utility Fund

8. Applicant in-kind services contribution: $ 34,931.00

II. PLANNING/PROJECT INFORMATION

9. Watersheds for Flood Protection Needs:

   This project proposal is applicable to flood prone watersheds within Extra-Territorial Jurisdiction (ETJ) and City Limits of Fort Worth.

10. Project Area for Economically Disadvantaged:

    The project proposal is not targeted for areas with economically disadvantaged.

11. The purpose of the project:

    There are two purposes: (a) enhance an early warning system, and (b) develop a flood response plan.

12. Severity of the existing or potential flood hazard:

    The City of Fort Worth is primarily vulnerable to flooding from rapidly occurring flash flood events that affect its neighborhoods. Development from increased impervious cover has decreased lag times from watersheds and contributed to increased peak flows along small streams and areas with undersized storm drains. The inner city areas, particularly older neighborhoods built in 1920s and 1930s within Loop 820, are especially vulnerable due to severely undersized drainage systems. Periodic flash floods over the past 15 years have flooded many hundreds of homes, businesses and churches, many on multiple occasions.

    Additionally, there have been 17 fatalities since 1986 within the City of Fort Worth from vehicles entering high water over roadways along small streams. The City undertook a Roadway Flood Hazard Assessment to review over 700 locations, of which 285 were identified for detailed inspection and hazard scoring. The City now has a High-Water Warning System at the 51 most hazardous crossings, set to trigger flashers when the water is rapidly rising or about to overtop a roadway. Notification is sent to the base station, triggering an email to key personnel regarding flasher location and depth. Although several of the most dangerous crossings have been replaced over the past ten years, funding is lagging for additional crossing projects.

13. Scope of Work (6 page limit): Attached at end of application.

14. How will the Project Reduce Loss of Life?

    Due to Fort Worth's geography, most streams and drainage sheds are relatively small and travel only a short distance before reaching either the Clear Fork or West Fork Trinity River. Prior studies have determined that stream gauging cannot give adequate advance warning when flash flooding is occurring. Further, rainfall from thunderstorms is quite variable based on where individual cells pop up and how long they linger in a certain area, so that it is impossible to predict which neighborhoods are most prone to localized flooding impact.

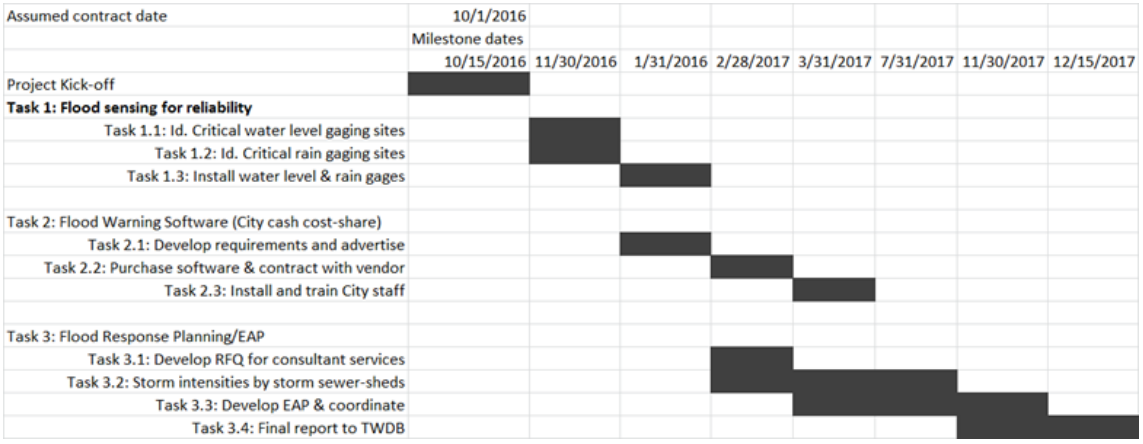
By installing an extensive rain gauge network and developing proper calibration and triggers, emergency responders can be notified to respond even as flash flooding is beginning to occur. This in turn allows for barricades to be installed and emergency vehicles to be mobilized in the affected neighborhoods in advance of the worst flooding. Real-time rainfall information, plus depth information from the City's existing High-Water Warning (HWWS) sites, can be shared with the City's partner agencies (NWS, TRWD, USACE, etc.) in order to further enhance their warnings and response, as well as with the public on a future website or even on a Reverse-911 system.

After the event, rainfall data as well as stream depth at HWW sites can be used to improve rainfall estimates from radar (Collaborative Adaptive Sensing of Atmosphere CASA radar and NWS-NEXRAD) measurements, as well as the City's own triggers. These can also be used to enhance the City's Emergency Action Plan (EAP) to ensure better coordination among City and external agency personnel, and to assist with long-term flood control planning. All of these efforts together will contribute to reduced loss of life both in an immediate flood event and in mitigation planning.

15. How will the Project Reduce Loss of Property?

The faster response time for emergency personnel (especially if combined with Reverse 911 notification) will allow citizens to move vehicles and personal property out of harm's way, as opposed to the current situation when citizen's discover flooding as it is already occurring on their property.

16. Schedule



17. Budget by Task:

TASK	DESCRIPTION	AMOUNT
1	Water level and Rain Sensing for Reliability and Resilience	$287,496.00
2	Advanced Flood Warning Software	$273,904.00
3	Flood Response Plan	$70,909.00
TOTAL		$632,309.00

18. Expense Budget by Category

CATEGORY	AMOUNT
Salaries & Wages (City match)	$24,948.00
Fringe (City match), 32%	$7,983.00
Travel (City match)	$2,000.00
Consulting Services contract (City match)	$100,000.00
Flood Warning Software (City cash match)	$250,000.00
Water level and rain gaging (TWDB funds)	$247,378.00
Overhead	NA
Profit	N/A
TOTAL	$632,309.00

Salaries and wages are based on mid-point of City's salary schedule for FY2016.

19. Qualifications and Direct Experience of Project Staff:

Ranjan S. Muttiah, Ph.D., P.E., CFM, Senior Professional Engineer, will serve as the City's project manager. Supporting City staff includes Cannon Henry, P.E., CFM, Senior Professional Engineer over Field Engineering (including maintenance of existing HWW system); Steven Eubanks, P.E., CFM, Chief Stormwater Engineer; Chris Johnson, P.E., CFM, Engineering Manager, and Elizabeth Young, GISP, GIS/IT lead.

Dr. Muttiah has nearly 25 years of experience as manager, leader, and team-member in national, Texas, and City urban water resources projects: among them, development team of SWAT model at Texas A&M/USDA-ARS, USDA-NRCS national hydrologic modeling, 10/12-digit sub-watersheds for Texas, Edwards recharge improvement from brush management (partly funded by TWDB), City water distribution system modeling, and Fort Worth flood control projects. Since joining City of Fort Worth's SWM/TPW Department in 2011, he was project manager of City's watershed flood studies (FEMA LOMR revisions) when he successfully managed nearly 40 different consultant contracts, water quality technical lead, master planner for MS4/post-construction and flood warning system. Dr. Muttiah has also published in peer reviewed journals with 4,700 citations from 51 publications (researchgate.net statistics). In his current capacity, he will be leading City of Fort Worth's effort to improve the reliability of the HWWS sensing and flood warning system.

Mr. Henry has worked in the City of Fort Worth's Stormwater Management Engineering Division since its existence in 2006. He currently serves as the City's lead stormwater Senior Professional Engineer over maintenance programs for stormwater infrastructure. In his role, he manages and oversees small capital project design and construction activities, supports and oversees stormwater related drainage complaints and investigations, manages the City's low-water crossing alert system, and provides general engineering support for the City's Stormwater Operation and Maintenance Division. Mr. Henry, has recently acted as Project Engineer for the expansion of the City's low-water crossing alert system, which currently includes over 730 various alert sensors that

provide real-time weather information to staff and other entities within and surrounding the Fort Worth area.

Mr. Eubanks has worked in the City's Stormwater program since 1999. He has overseen new development review, capital project management, flooding and drainage complaint investigations, and engineering assistance for maintenance projects. He assisted in the development of the City's Stormwater Utility and the 2006 Fort Worth *Storm Water Management Design Manual* and most recently oversaw development of the City's Stormwater Master Plan. Mr. Eubanks currently serves as Co-chairman of the Texas Floodplain Management Association's Stormwater Committee and was named Engineer of the Year by TSPE Fort Worth Chapter in 2016.

Chris Johnson, P.E., CFM, is the City's Stormwater Utility Engineering Manager, responsible for planning, capital project development, and oversight of the City's High Water Warning System. Mr. Johnson has 32 years of flood hazard reduction experience, including stormwater master planning, hydrologic and hydraulic modeling, flood hazard mapping, dam safety, and emergency action plan preparation. Mr. Johnson's role will be to provide management oversight, allocate resources, and serve as a technical advisor to the project team.

Elizabeth Young, Elizabeth Young, GISP has been part of the City's Strom Water Management Division since 2009 and brings 22 years of GIS experience and 10 years of IT Management to the team. Mrs. Young was brought on board to direct the GIS Inventory and Assessment Project which mapped and assessed the condition of over 300,000 assets. As IT Manger, she oversees technology initiatives including the implementation of a work order/asset management system and a new High Water Warning System. She also has oversight for Storm Water commercial billing. Mrs. Young currently sits on the Accela Advisory Council and has recently completed her Lean Six Sigma Certification.

20. Method of Monitoring Project Progress:

Each of the tasks in this project has specified deliverables with deadlines. The project manager will be responsible for ensuring tasks are completed by the deadline. Periodic progress and review meetings will be held with key project personnel. Meeting minutes identifying decisions made and outstanding action items will be prepared and distributed to participants. Schedules will be specified in contracts with vendors and consultants and invoices monitored for compliance with deliverables. The vendor contracts will specify 24/7 availability. The actual performance of the flood warning system obviously is rainfall-dependent. Following installation of the different components (rain and water level gaging and flood warning software), measurements will be checked against existing gages for QA/QC. Major problems will be identified and immediately rectified.

III. WRITTEN ASSSURANCES

21. The Stormwater Management Division of the Transportation and Public Works Department (TPW) is responsible for planning and executing flooding related projects in the City of Fort Worth as authorized by City Ordinance No. 16781.

22. The City of Fort Worth participates in the National Flood Insurance Program (NFIP) and is NFIP community number: 480596.

23. The proposed project does not duplicate existing projects.

IV. RESOLUTION

24. Expense budget by category for the detailed scope of work by tasks:

City salaries based on mid-point of FY2016 salary schedule				
		Personnel	**Total Hours**	**Cost**
Item				
Task 1	Rain and water level gaging			
	Task 1.1	Sr. PE, Engr. Manager, Engr. Tech	24	$1,255
	Task 1.2	Sr. PE, Engr. Tech	40	$1,962
	Task 1.3	Sr. PE, Engr. Tech	164	$5,901
	Equipment including installation	TWDB cost share		$247,378
	Travel	City match		$1,000
	Consultant services	City match		$30,000
			Task-1 total	$287,496
Task 2	Advanced Flood Warning Software			
	Task 2.1	Sr PE, Engr. Manager, Engr. Tech	24	$1,283
	Task 2.2	Sr PE, Engr Tech, IT Analyst	28	$1,073
	Task 2.3	Sr PE, Engr Tech, IT Analyst	38	$1,549
	Consultant services	City match		$20,000
	Software purchase	City match		$250,000
			Task-2 total	$273,905
Task 3	Flood Response Planning			
	Task 3.1	Sr PE, Engr. Tech, Engr. Manager	16	$918
	Task 3.2	Sr. PE, Engr. Tech	160	$9,495
	Task 3.3	Sr. PE, Engr. Tech	140	$8,240
	Task 3.4	Sr. PE	20	$1,256
	Consultant services	City match		$50,000
	Travel	City match		$1,000
			Task -3 total	$70,909
ALL TASKS				$632,309
			City match %	60.9

25. Authorization for the grant application from the governing body of the City of Fort Worth is attached.

(Question 13) SCOPE OF WORK

The City of Fort Worth has invested in a flood alert system with flashers at 51 hazardous road crossings. The system also provides early warning to Stormwater Maintenance and emergency personnel of impending flood levels at these crossings. The main thrust of this funding request to make this alert system more reliable: low-water crossings will be gaged with more resilient bubbler sensors, software will be upgraded, and the rain network will be expanded to more accurately capture the spatial variability of rainfall. The City of Fort Worth will provide matching funds through purchase of flood warning software, funding of consultant services, and through City staff time on the project. Reliability of the gaging and communication system that leads to reduction of false positive and false negative signals from the current sensor network is critical for information used by flood emergency responders.

Background

The starting point for this proposal is the City's High Water Warning System (HWWS). The system consists of stage and precipitation gages at 51 low water crossings, 5 lake levels, and 2 dedicated weather stations. Warning flashers are automatically turned on when rising flood waters exeeed a pre-defined threshold level; nominally the threshold levels are set at rising waters at 1' below low-chord of crossing.

The reliability of the system is critical because City's Stormwater maintenance crews respond to the flood alerts and deploy barricades. When there's wide spread flooding and when personnel are stretched thin, false alerts due to poor gage readings can reduce the effectiveness of the deployment of personnel. Enhancing the current HWWS sensors and software will create better situational awareness for City and external partners, allow better integration of weather and flooding information with forecasting and weather monitoring tools (NEXRAD and CASA), and improve the response (but avoiding false alarms) of emergency personnel.
The HWWS uses the Automated Local Evaluation in Real Time (ALERT) protocol, using VHF radios and a single repeater to transmit to the base station located at the South Holly Water Treatment Plant. A repeater is located at the top of Burnett Plaza Building and functions to receive signals from sites that do have a reliable communication link to the base station, and passes signals along to the base station. The equipment used in the existing HWWS is supplied by High Sierra Electronics, Inc. and DataWise is the software that is used to monitor the sensors and issue alerts.

The ALERT protocol is an event-driven, real-time, one-way transmission system with small data payload: the system consumes low amounts of power, notification to the receiver station takes place as the event occurs, and the system is relatively low-cost. The short comings of the ALERT system are that it is prone to high rates of lost and erroneous data because the event transmission can lead to data collisions (on average about a 30-35% fail rate), and scaling to a larger sensing network leads to larger messaging sizing and thereby even more data collisions. The ALERT2 protocol has addressed many of the limitations of the ALERT system. The new gaging sites funded through this project will be phased in through ALERT 2.

The City partners with a number of agencies involved in flood warning and forecasting: the National Weather Service (NWS) Fort Worth Weather Field Office (WFO) receives gage data collected by City of Fort Worth, and Tarrant Regional Water District (TRWD) and USACE coordinates on lake levels and releases. The NWS WFO collects and distributes precipitation data from its own weather stations at the Texas Motor Speedway, Meacham and Dallas/Fort Worth airports. The NWS NEXRAD dual-polarization radar station that serves the region is located the Spinks Airport. Weather and flood forecasts issued by the NWS are received and passed onto relevant City personnel by the City's Office of Emergency Management (OEM). The City at this time does not have a "real-time" flood forecasting capabilities and relies on the NWS flood forecasts.

There are two major lakes that are in the City of Fort Worth: Lake Worth, and Lake Benbrook. Lake Worth is does not have significant amount of storage and mostly acts as a "pass through" lake for the much larger Eagle-Mountain lake, which is operated by TRWD, just upstream of Lake Worth. Flood levels at Lake Worth are monitored by the Water Department and alerts issued to Lake Worth residents in coordination with the TRWD. The releases of Lake Benbrook are controlled by the USACE.

Project Tasks

The City works with a number of agencies involved in flood warning and forecasting: the National Weather Service (NWS) Fort Worth Weather Field Office (WFO) collects rain data collected by City of Fort Worth, and other cities and the Tarrant Regional Water District (TRWD). The NWS WFO collects and distributes precipitation data from its own weather stations at the Texas Motor Speedway, Meacham and Dallas/Fort Worth airports. The NWS NEXRAD dual-polarization radar station that serves the region is located the Spinks Airport. Weather and flood forecasts issued by the NWS are received and passed onto relevant City personnel by the City's Office of Emergency Management (OEM). The City at this time does not have a "real-time" flood forecasting capabilities and relies on the NWS flood forecasts.
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<u>Task 1: Water level and Rain Sensing for reliability and resilience</u>
Hydraulics at pier/embankment bridges and culvert crossings is not straight forward, and flood conditions can significantly alter the dynamics of flood flows up-stream and downstream of crossings. The current level sensing used by Fort Worth is dependent on debris free flood flows water levels are sensed by pressure transducers (PT tubes). The objective of this task is to investigate, and appropriately place additional sensors (flood proofed bubbler sensors), at specific monitoring sites that are part of the current HWWS sites. The specific attributes of many of these crossings are: a). low levels of flood frequency service; b). poor visibility of

hazard; c). high traffic volume at peak hours; d). past fatality and/or rescues at crossing; e). downstream threat, and f). length of traffic detour.

Currently, water levels once they pass a trigger level are treated independently and no cross-validation with other hydraulically connected sensors is performed. For the sites that have been selected, the software (which the City will purchase as cost-share for this project) will be programmed to check for cross-validation between upstream and downstream gages before alerts are issued. For this project effort, it is anticipated that 10 upstream/downstream bubbler type water level sensors will be placed at different locations that are part of the current HWWS gaging network to test cross-validation procedure. A primary finding from this task will be whether having different sensor types (bubbler sensor) sensing at appropriate downstream and upstream locations provides better reliability and resiliency of water level measurements at low-water crossings.

The HWWS uses tipping bucket sensors to measure rainfall and is generally well suited for flood warning purposes (precision to 0.04"). This project will supplement current rain gage (1 per site) with an additional rain gages selected sites for cross-validation of rain fall measurements during storm events. The City has been working with the CASA community (see http: www.nctcog.org/ep/Special_Projects/CASAWX) for more accurate weather (rainfall) forecasting in the DFW metroplex. The rapid refresh (X-band every 5 minutes) CASA radar has pre-programmed rainfall rate calibration parameters that are being refined for the Dallas-Fort Worth metroplex. Due to the extreme nature of flood events, relying on a single rain gage (with appropriate measures at gaging site) at a site has been shown prone to rainfall capture problems when compared against radar measurements. Placement of additional rain gages at a specific site will allow for better comparison and calibration of CASA and NEXRAD rainfall rates. Commercial and NWS forecast (e.g. Rapid Refresh RAP and HRRR products) providers place considerable value on use of rain corrected radar measurements for forecasts.
The City currently maintains and monitors 38 precipitation gages. An AECOM study contracted by the City of Fort Worth showed that adequate coverage of rainfall patterns for the City required 30 rain gages in addition to existing rainfall sites. Due to the importance of rainfall, 20 new rain gaging sites using ALERT2 will be identified and gaged for this project. The locations will be based on: availability of City right-of-way or participation from private entities, criticality of location (locations at storm sewer-shed divides to catch storm frontal movements will be preferred), obstruction clearance, height (high buildings in the downtown), and security at site to prevent vandalism etc. No new sites (beyond existing low-water crossings) for flood water levels is planned through this grant application.

The gaging data from this project will aid in on-going and future collaborative efforts with other cities in the DFW metroplex to more accurately track and forecast high intensity storm events. Specific sub-tasks are given below.

Specific sub-tasks are given below:

Task 1.1: Identify critical flood prone low-water crossings at which to install additional upstream and downstream gages with different type sensors. Expect to supplement with additional water level gages at 10 sites. Deliverable: Sub-set of low-water crossings for supplemental gaging. Milestone date: 11/30/2016.

Task 1.2: Identify critical sites for installation of dedicated rain gages. Past AECOM study for rain gages will be used as basis for expansion of the rain gage network to 20 new sites, and installation of additional 20 rain gages at existing sites for validation. Deliverable: Map and locations for new rain gaging sites. Milestone date: 11/30/2016.

Task 1.3: Install the sensors, and ALERT2 communication system. Deliverable: successful installation and testing of equipment (contracted to vendor through existing HWWS maintenance contract). Milestone date: 1/31/2017.

Task 2: Advanced Flood Warning Software Acquisition

The City currently uses the Datawise software (v7.5 and v10) tied to a server to receive and monitor the HWWS gages. Some of the limitations of the Datawise software were found to be: lack of local administrative control capabilities, difficulty of testing HWWS with simulated input, lack of user friendliness, and difficulty of group communication settings. Datawise will be phased out and replaced with new software as City's cost-share for this project.

The AECOM study of the software requirement for a flood warning system identified the following primary requirements:

(1) Capability to ingest data via one-way (ALERT) and two-way communication (ALERT2)
(2) Control of external devices and alert generation
(3) Monitoring, analyzing, and error checking of data in real-time
(4) Display of data and sensor status on maps and in user defined format
(5) Data import and export in wide variety of formats (APIs, XML etc.), including mapping applications
(6) Remote access and viewing (e.g., on cell phone app)
(7) Data mining
(8) Strong data back-up capabilities
(9) 24/7 support.

These requirements will be an important part of software selection and procurement. The hardware (server), and technical support for software will be provided for this project at City's cost. The total estimated external costs (excluding staff time) is $250,000 which is included the City's 5-year capital expense plan. Specific sub-tasks are given below:

Task 2.1: Develop software requirements, and advertise call for flood warning software. Deliverable: RFQ for flood warning software to be advertised and selected as per City procurement requirements. Milestone date: 1/31/2017.

Task 2.2: Procure software satisfying City requirements. Deliverable: Purchase and contract with software vendor. Milestone date: 1/31/2017.

Task 2.3: Install software and train City staff on software usage. Deliverable: Installation and testing of flood warning software. Milestone date: 3/31/2017.

Task 3: Flood Response Planning (here called Emergency Action Plan, EAP)

City staff and consultant will be engaged in development of an EAP as part of this project. The goal of a Flood EAP is to prepare a defined set of actions based on flood trigger events and help remove as much "chaos" as possible prior to, during, and following a flood emergency. A consultant will be selected by City staff involved in this project and will follow City's solicitation and selection requirements. Consultant services will be provided as City's cost-share. The EAP will consist of the following main elements.

1. Planning
    a. Identification of flood hazards and risks to people and property. This effort will be undertaken by storm drain sewer-sheds by City assets (roadway crossings, critical facilities etc.) by flooding rainfall intensities.
    b. Develop desired actions: pre-staging actions (neighborhood alerts, personnel etc.) at hazardous areas from step (a).
    c. Document clearly assigned roles and responsibilities: previous effort at master planning which identified the "connectivity" between agencies and personnel during flood events will be used to document and vet this document through the City's emergency response community. The document will use unambiguous language, and develop a communication plan.
    d. Provide flood preparedness and actions education for the public: make data available to public via website, text alerts, social media data rainfall intensities and flooding levels of service at hazardous sites by storm sewer-shed from step (a).
2. Operations
    a. Provide periodic training for O&M staff: The O&M document for the existing system will be updated for the improvements made through this project effort.
    b. Staffing and monitoring: Holistically organize and update the City's existing on-call lists and emergency O&M procedures, exchange updated on-call lists between relevant City departments and external partners (NWS, TRWD, USACE), and ensure City's OEM has flood support personnel (Flood Operations Engineer, FOE) and resources during emergencies.
    c. Flood Operations: The FOE in coordination with OEM escalates level of response and readiness of flood response staff, following procedures in the Flood EAP. Deviations from the EAP will be documented and discussed during post-flood assessments.
3. Post-Flood
    a. Flood forensics: police, fire department, and SWM field maintenance flood response reports are compiled and appropriate level of SWM staff investigation is determined, low-water crossings and flasher/warning response to flood events are

investigated, and performance of critical Stormwater capital assets in impacted areas (storm drain lines and culverts) are investigated, a flood characterization report (nature of flood event, consequences, and response) is generated for high intensity storms.

b. Update of Flood EAP: The Flood EAP is updated and broadcast to relevant City staff based on lessons learned, communication among staff is intensified depending on flood event.

c. Maintain Flood Response database: A dedicated database for flooding and response is updated with the event and response.

Specific sub-tasks are given below:

Task 3.1: Develop RFQ & select consultant to assist with development of EAP. Deliverable: RFQ and consultant selection. Milestone date: 2/28/2017.

Task 3.2: Identify critical rainfall intensities by storm sewer-sheds. Program threshold rainfall intensities in flood warning software for alerts. Stormwater division's past watershed hydrology & hydraulics models, historical observations by staff, the city-wide Innovyze ICM hydraulic model at 100 feet grids, among other models, observations and data will be used for this task. Deliverable: City-wide map of flood intensities by storm sewer-sheds. Milestone date: 7/31/2017.

Task 3.3: Develop EAP along with coordination meeting with relevant stakeholders as discussed above. Deliverable: EAP report and meeting minutes. Milestone date: 11/30/2107

Task 3.4: Write final report of project findings for the benefit of other communities and project deliverable to TWDB. Deliverable: Final project report. Milestone date: 12/15/2017